

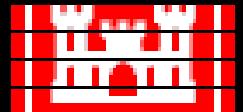
# **A Spill Management Information System for Freshwater Incidents**

**Edsel B. Daniel, James P. Dobbins, Paul H. Martin,  
Eugene J. LeBoeuf, Mark D. Abkowitz**

**Vanderbilt University  
Department of Civil and Environmental Engineering**

**in conjunction with**

**The Nashville District and the Engineering Research and Development  
Center, U.S. Army Corps of Engineers**



# Presentation Outline

- Background
- Project Objectives
- Conceptual Design and System Architecture
- Water and Air Quality Models
- Model Execution
- Spill Scenario Example
- Project Accomplishments
- Current and Future Work

# Background

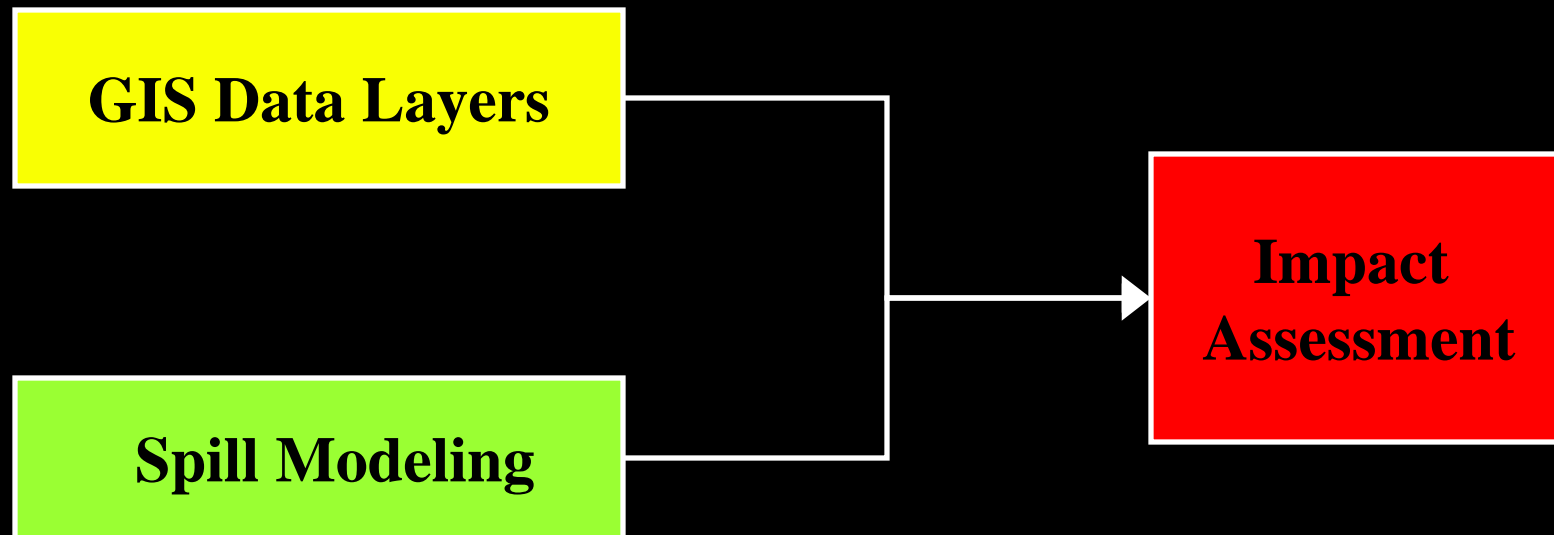
- **U.S. Army Corps of Engineers (USACE) maintains over 11,000 miles of navigable waterways which include numerous critical marine elements:**
  - **Water supply, recreation areas, and sensitive environmental areas**
- **Marine transportation is considered one of the nation's most efficient, safe, and economical modes of freight transport.**
- **Hazardous materials comprise a large portion of barge transported commodities, placing communities along navigable waterways at risk of exposure to toxic chemicals in the event of a collision, grounding, or terrorist action.**
- **Managing a navigable water body chemical spill response involves coordination and communication among numerous federal, state, and local entities posing challenges in the areas of:**
  - **Retrieving characteristic chemical data**
  - **Jurisdictional responsibility of responding agencies**
  - **Location of waterway access points**
  - **Community notification**

# **Project Objectives**

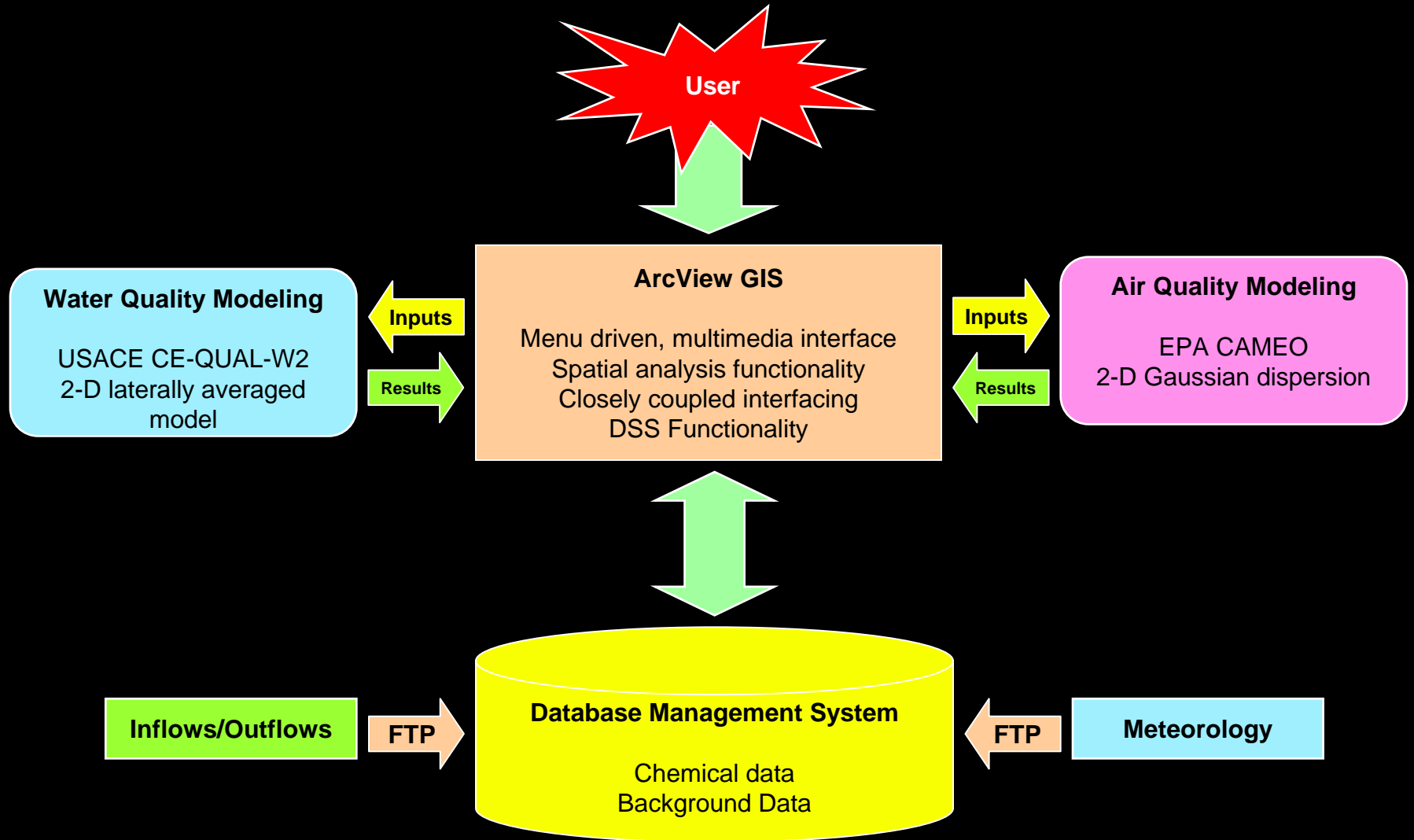
**Develop a spill management information system (SMIS) that:**

- **Addresses accidental releases and terrorist incidents**
- **Provides the capability to perform simulation training, contingency planning, and real-time incident management**
- **Utilizes advanced information technologies to deliver timely and accurate information in a spatial-based framework**

# Conceptual Design

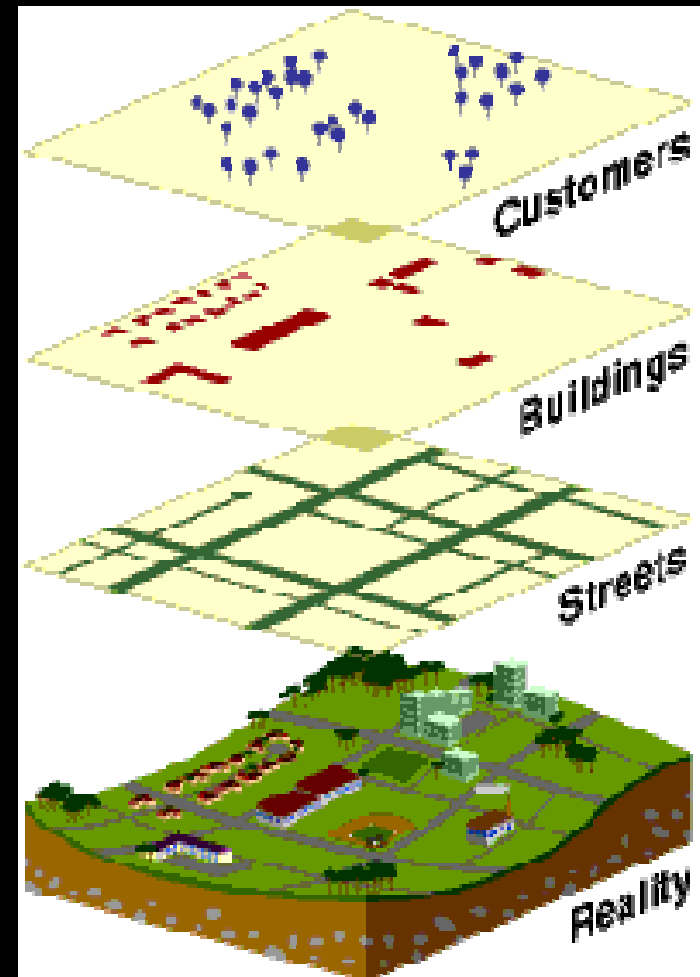


# System Architecture



# Geographic Information Systems

GIS is a system of computer software, hardware, and data to help manipulate, analyze, and present information that is tied to a spatial location.

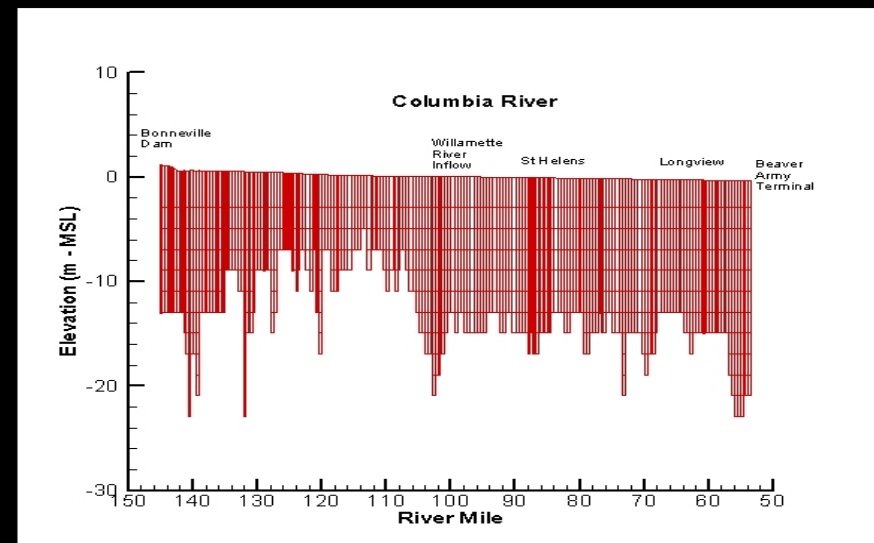
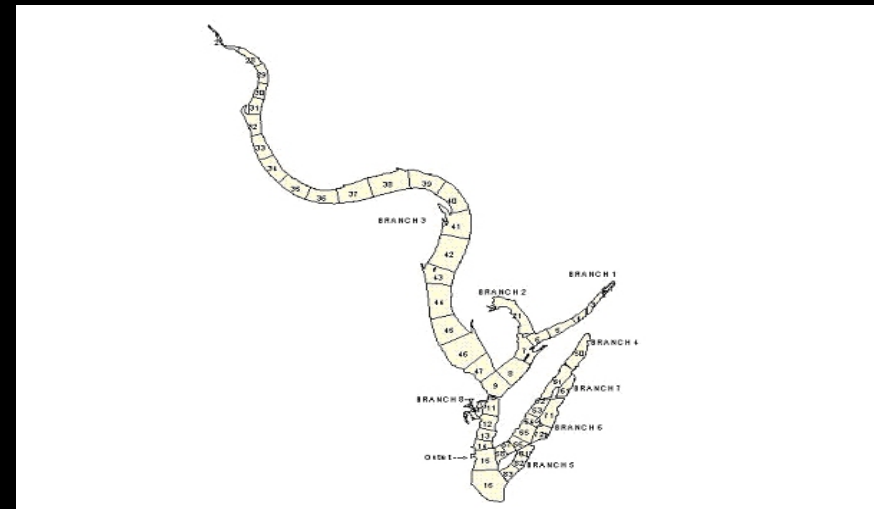


# CE QUAL W2

**2-D, longitudinal/vertical hydrodynamic and water quality model applicable to rivers, lakes, reservoirs, and estuaries.**

**Developed by Portland State University in conjunction with USACE Waterways Experiment Station (WES).**

**Version 3.1 developed for the Cheatham Reach of the Cumberland River.**





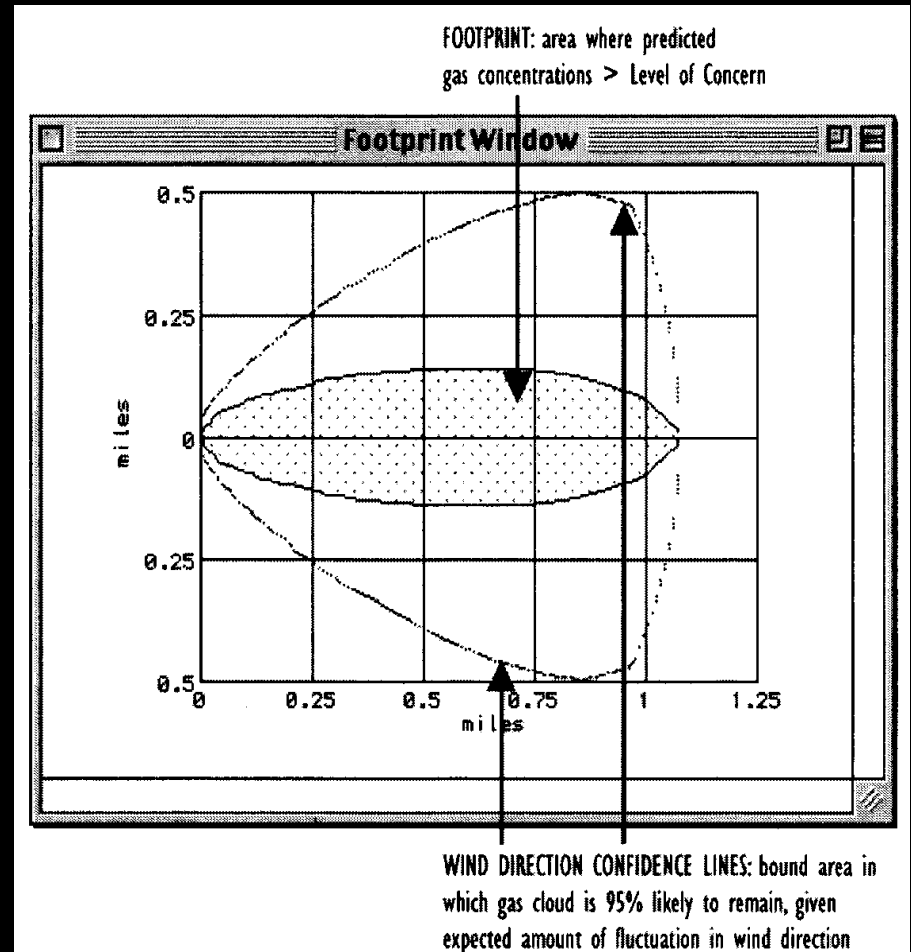
# CAMEO

**Computer Aided Management of  
Emergency Operations (CAMEO).**

**Suite of software programs used to plan for  
and respond to chemical emergencies  
developed by the USEPA and NOAA.**

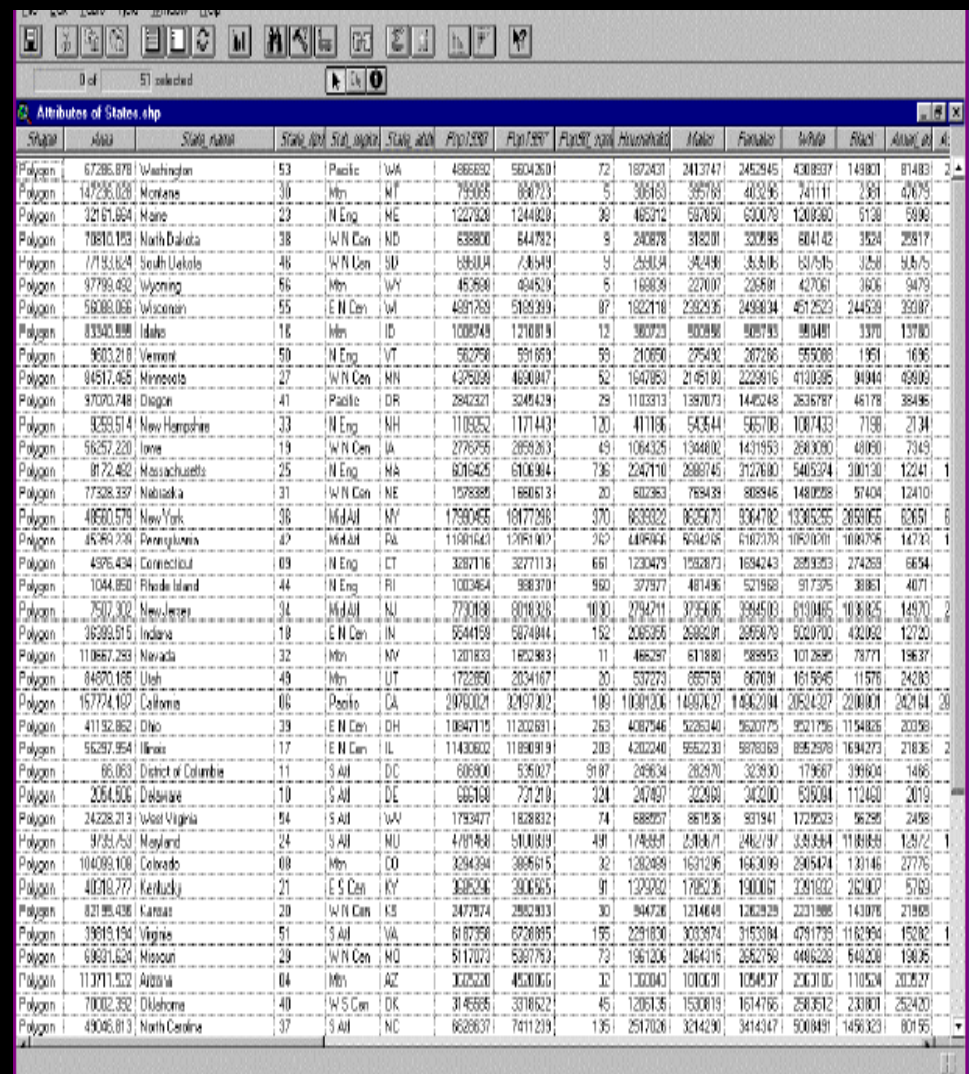
**Includes a Chemical Library, Areal  
Location of Hazardous Atmospheres  
(ALOHA) and Mapping Applications for  
Response, Planning, and Operational Tasks  
(MARPLOT).**

**Generates a 'cloud footprint',  
encompassing the area where ground level  
concentration of a pollutant gas exceeds a  
pre-determined Level of Concern (LOC)**



# Database Management System

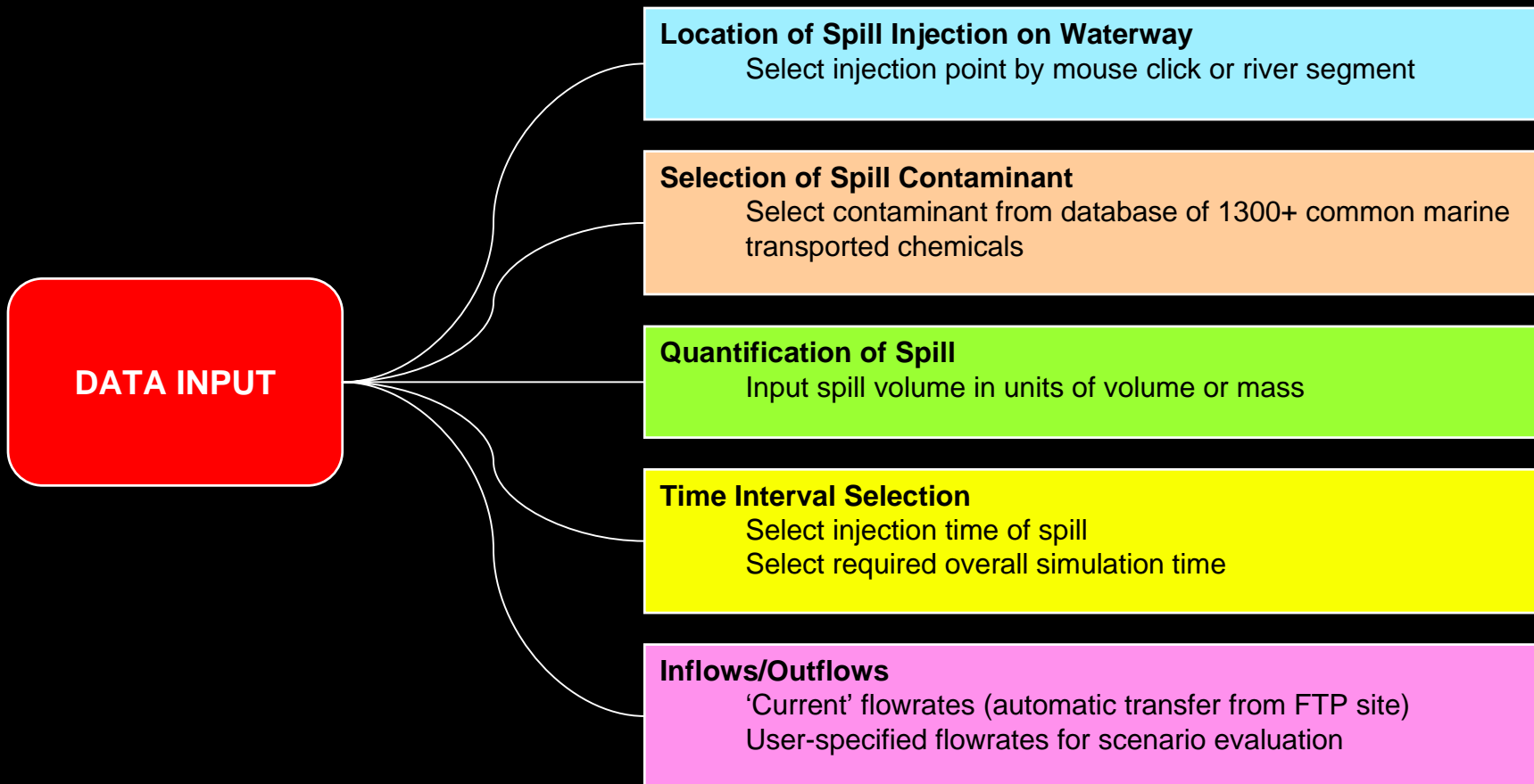
Database Management System stores chemical information and feeds meteorological data to the system.



The screenshot shows a database management interface with a table titled "Attributes of States.shp". The table contains 15 columns: State, Area, State\_name, State\_abb, Stat\_abb, State\_abb2, Pop1997, Pop1998, Pop1999, Househld, Male, Female, White, Black, Asian, and A. The table lists data for all 50 US states and the District of Columbia, sorted by Area in descending order. The interface includes a toolbar at the top with various icons for file operations, a status bar indicating "0 of 51 selected", and a scroll bar on the right.

State	Area	State_name	State_abb	Stat_abb	State_abb2	Pop1997	Pop1998	Pop1999	Househld	Male	Female	White	Black	Asian	A
Polygon	67285.878	Washington	53	Pacific	WA	4866832	5034263	72	1872431	2413747	2452945	4308337	14803	81403	2
Polygon	147235.026	Montana	30	Mtn	MT	795065	880713	5	305163	355763	402495	741111	2381	47675	
Polygon	32161.864	Maine	23	N Eng	ME	1227928	1244829	99	485212	507690	500079	1305980	5138	5998	
Polygon	70810.153	North Dakota	38	W N Cen	ND	638800	644782	8	248878	318201	320898	804142	3524	29817	
Polygon	77183.824	South Dakota	46	W N Cen	SD	688304	736549	9	254034	342498	353105	631515	3258	93575	
Polygon	97793.452	Wyoming	56	Mtn	WY	453698	494529	5	188838	227007	225891	427061	1606	9479	
Polygon	56083.086	Wisconsin	55	E N Cen	WI	4891769	5188389	87	1821118	2352335	2498834	4512522	244529	35087	
Polygon	83340.898	Idaho	16	Mtn	ID	1008748	1218819	12	380723	503898	585785	981481	3370	13780	
Polygon	9603.218	Vermont	50	N Eng	VT	562298	591869	59	210890	275432	287285	555088	1951	1696	
Polygon	94517.465	Minnesota	27	W N Cen	MN	4375099	4690947	52	1547853	2145183	2229916	4110395	94944	4508	
Polygon	97070.748	Illinois	41	Pacific	DR	2842321	3049429	28	1103313	1387073	1445248	2636787	46178	38486	
Polygon	9353.514	New Hampshire	33	N Eng	NH	1103252	1171443	130	411186	545544	585708	1007433	7198	2134	
Polygon	56257.220	Iowa	19	W N Cen	IA	2776255	2858263	49	1084325	1348802	1431953	2803300	40890	7343	
Polygon	8172.482	Massachusetts	25	N Eng	MA	6016425	6106904	736	2247110	2888745	3127680	5405394	300130	12241	1
Polygon	77328.337	Nebraska	31	W N Cen	NE	1528385	1686513	20	802363	768438	808846	1481828	57404	12410	
Polygon	48660.579	New York	36	Mid Atl	NY	17890455	18477286	370	8633022	10350771	10364782	13305255	2653055	82651	6
Polygon	45494.738	Pennsylvania	42	Mid Atl	PA	11981543	12761407	262	4409464	5346765	5187373	10510101	1080756	14732	1
Polygon	4376.434	Connecticut	09	N Eng	CT	3287116	3277113	661	1230479	1582873	1694243	2893353	274269	6854	
Polygon	1044.850	Rhode Island	44	N Eng	RI	1003464	998370	950	373777	481436	521958	917395	38861	4071	
Polygon	7517.302	New Jersey	34	Mid Atl	NJ	7733188	8018328	1030	2742711	3754085	3945181	6110485	1018825	14570	2
Polygon	36393.515	Indiana	18	E N Cen	IN	5644158	5874944	152	2085355	2692091	2859879	5203700	432092	12720	
Polygon	110667.285	Nevada	32	Mtn	NV	1201833	1452383	11	486297	611880	588853	1012685	78771	19637	
Polygon	84670.185	Utah	49	Mtn	UT	1722890	2034167	20	537273	665758	867091	1615845	11576	24283	
Polygon	157724.187	California	06	Pacific	CA	29760021	32197302	189	10381204	14876727	16362384	20524227	2208081	242164	28
Polygon	41192.852	Ohio	39	E N Cen	OH	10647115	11202891	263	4087546	5285340	5520775	9521795	1154805	20398	
Polygon	55297.954	Illinois	17	E N Cen	IL	11430602	11890919	203	4202240	5552231	5878369	8952578	1694273	21836	2
Polygon	66.063	District of Columbia	11	S Atl	DC	689900	535027	9187	269634	282970	323800	179687	399604	1486	
Polygon	2054.906	Delaware	10	S Atl	DE	688168	737219	324	247487	322498	343200	505094	112460	2019	
Polygon	24238.213	West Virginia	54	S Atl	WV	1793477	1828832	74	688267	861936	931941	1729523	56290	2498	
Polygon	9733.753	Maryland	24	S Atl	MD	4781468	5100819	491	1748367	2316671	2482197	3391554	1188888	12572	1
Polygon	104089.108	Colorado	08	Mtn	CO	3284354	3886515	32	1282688	1671205	1663089	2905474	138146	27776	
Polygon	40181.777	Kentucky	21	E S Cen	KY	3685296	3904965	91	1339782	1785236	1900061	2261822	262007	5769	
Polygon	82195.436	Kansas	20	W N Cen	KS	3477974	3802933	30	944726	1214648	1262829	2231886	143078	21808	
Polygon	39613.154	Virginia	51	S Atl	VA	6187398	6726895	195	2291830	3033674	3153384	4791793	1162954	15282	1
Polygon	69631.624	Missouri	29	W N Cen	MO	5117073	5367763	73	1961206	2464315	2652789	4485228	540238	15836	
Polygon	113711.522	Arizona	04	Mtn	AZ	3025220	4520865	32	1000043	1010091	1054537	2003021	110524	202527	
Polygon	70002.352	Oklahoma	40	W S Cen	OK	3145585	3318622	45	1261335	1530819	1614785	2503512	230801	252420	
Polygon	49046.813	North Carolina	37	S Atl	NC	6628637	7411219	135	2517026	3214240	3414347	5008491	1456323	80155	

# SMIS Data Input



# SMIS Data Input

**QUALW2- INPUT PARAMETERS** ✕

**CONSTITUENT**

Name: [Select Constituent]

☒ Volume [Enter Spill Volume] [Cu. Feet]

☐ Mass [Enter Spill Mass] [Kg]

**SPILL DURATION**

Start Date(MM:DD)/Time(HR:MIN)

End Date(MM:DD)/Time(HR:MIN)

**LOCATION OF SPILL INCIDENT**

Waterway Name: [Cumberland River]

Segment ID: [86] Zoom to Segment

**SIMULATION**

Start Date(MM:DD)/Time(HR:MIN)

Same as Spill Start Date/Time

Duration: ☒ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 days

Run Map Output Close Help

# SMIS Data Input

**Dam Flow Settings** [X]

Change Live Dam Flow and Weather File

**OLD HICKORY DAM FLOW**

☐ Live Connection FLOWRATE: 424.755 Cu. Meters/sec

☒ Enter Flow

DURATION: Start(MM:DD:HR) End(MM:DD:HR)

Same as Simulation Duration 1 1 0 1 2 0

**PERCY PRIEST DAM FLOW**

☐ Live Connection FLOWRATE: 0.28317 Cu. Meters/sec

☒ Enter Flow

DURATION: Start(MM:DD:HR) End(MM:DD:HR)

Same as Simulation Duration 1 1 0 1 2 0

**CHEATHAM DAM FLOW**

☐ Live Connection FLOWRATE: 396.438 Cu. Meters/sec

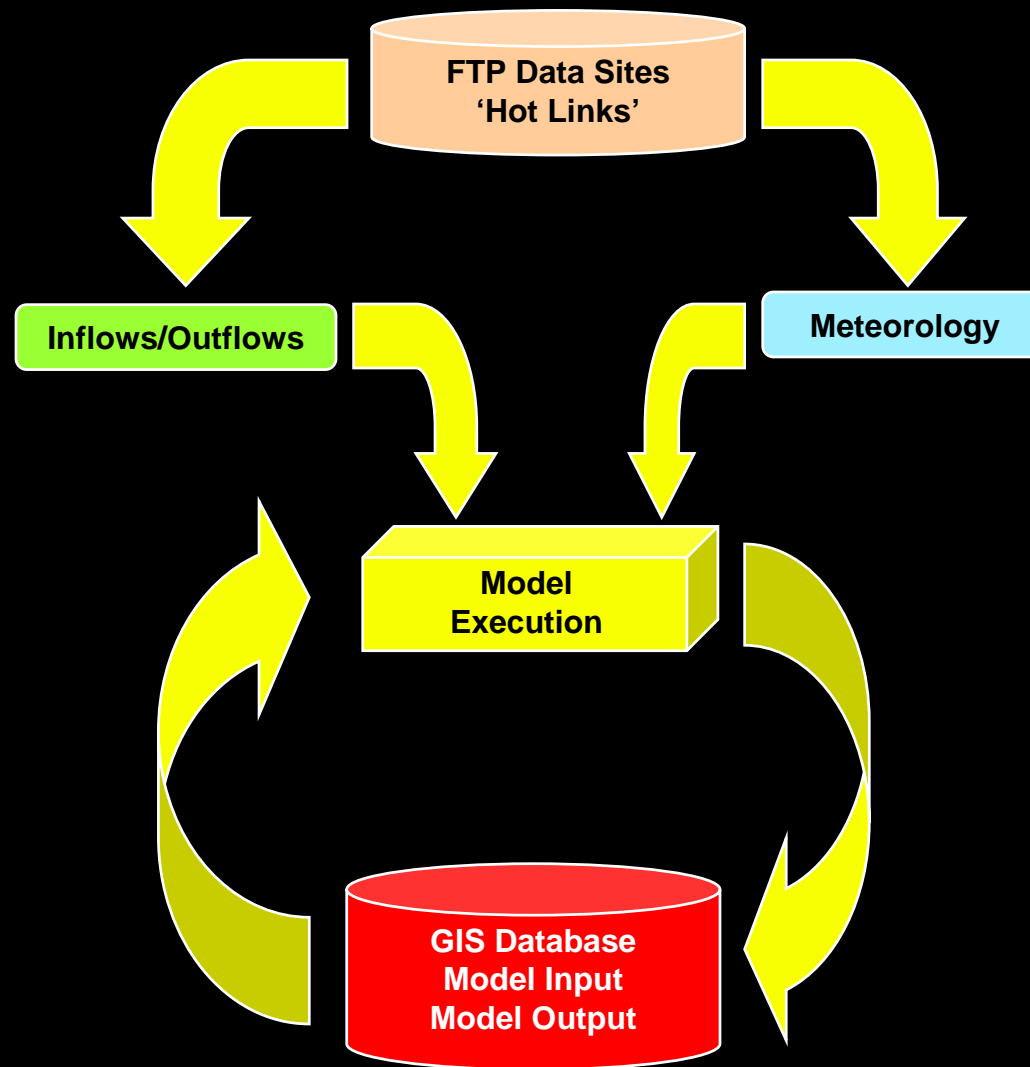
☒ Enter Flow

DURATION: Start(MM:DD:HR) End(MM:DD:HR)

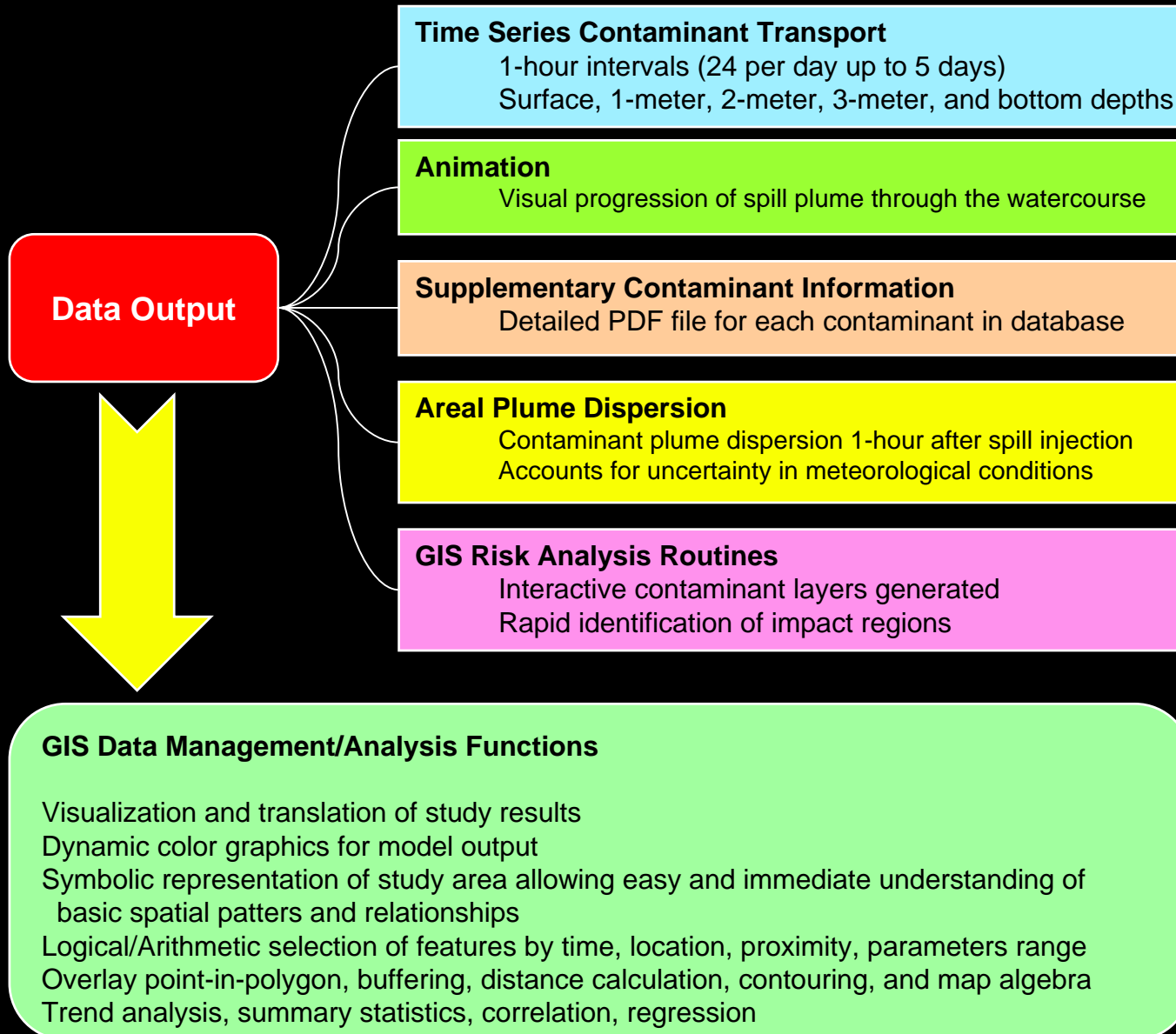
Same as Simulation Duration 1 1 0 1 2 0

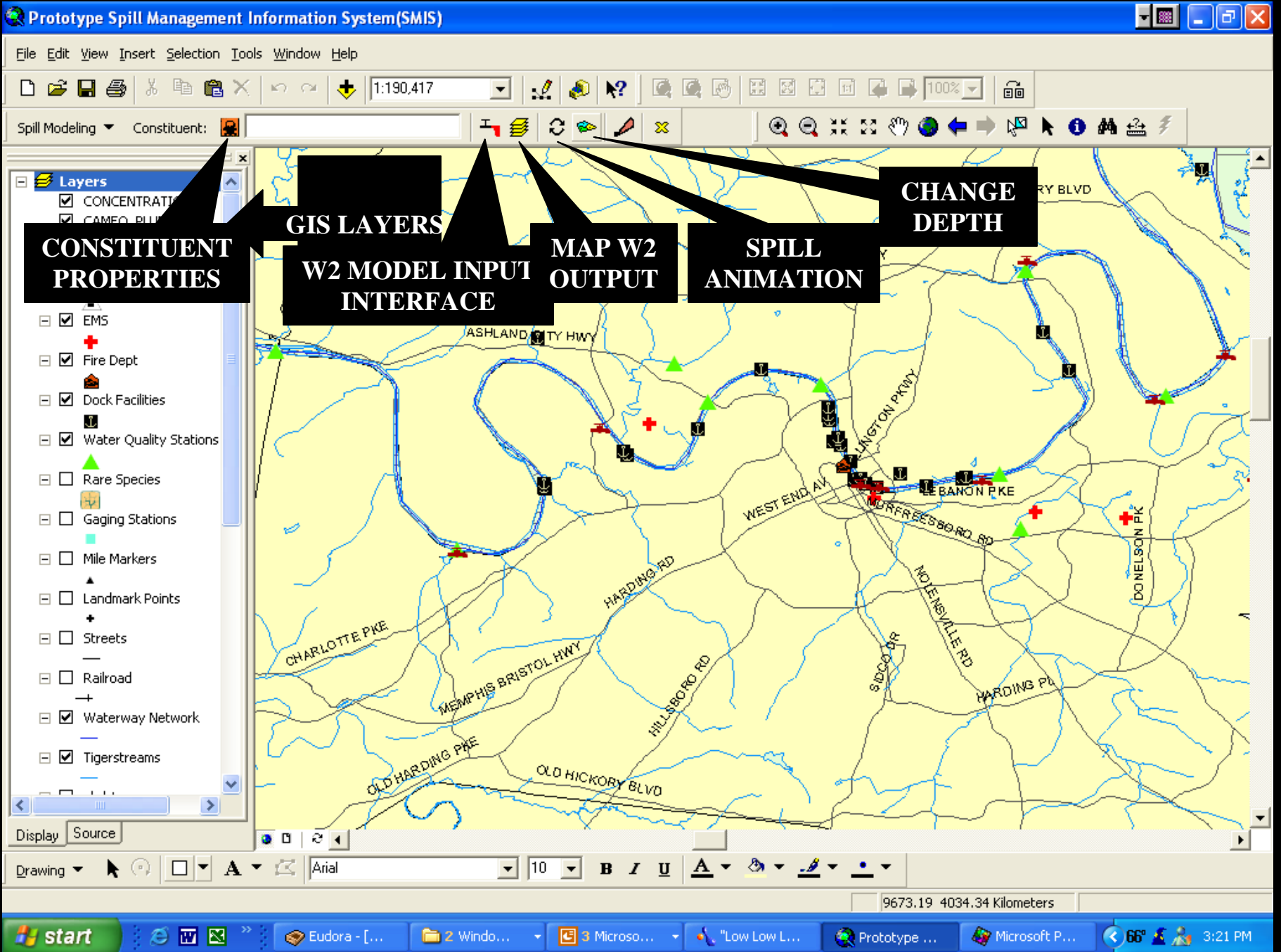
Ok

# SMIS Model Execution



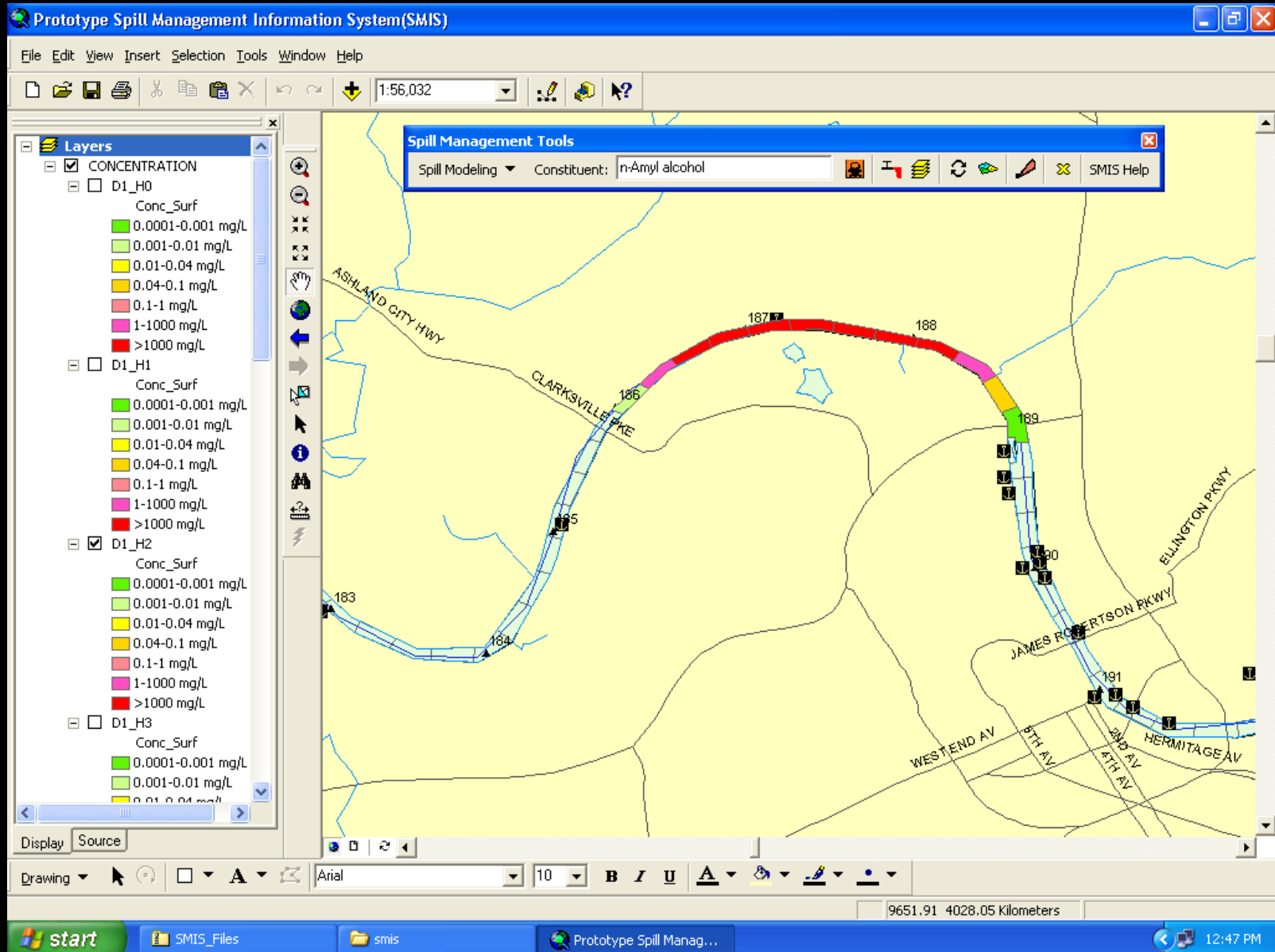
# SMIS Output



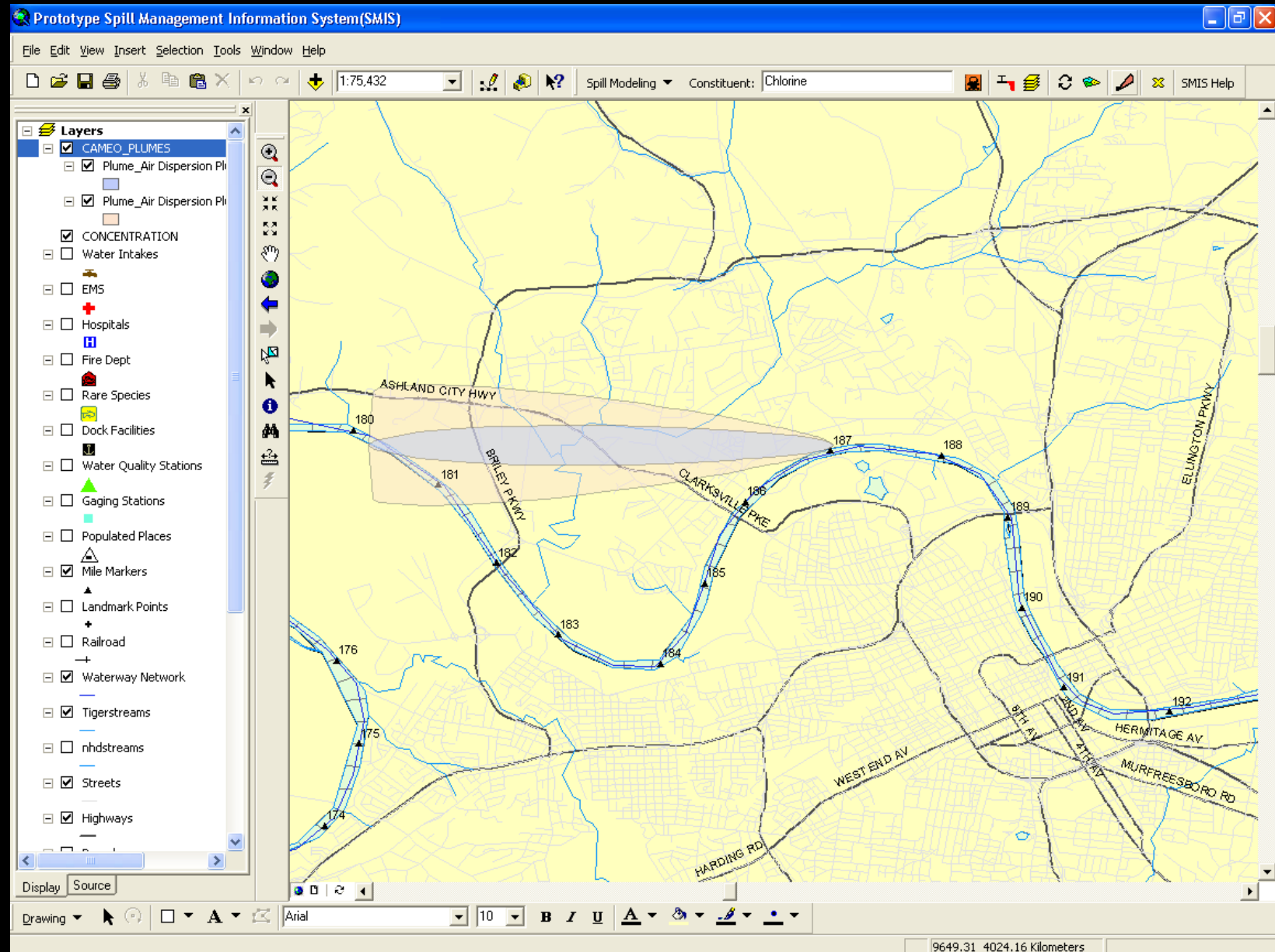




# Sample Output – Surface Water Contaminant Dispersion



# Sample Output – Air Dispersion



# Functionality Summary

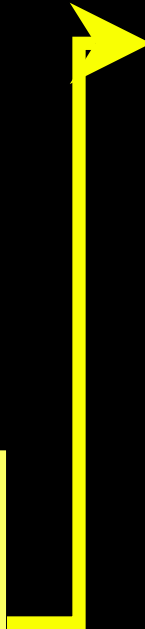
## •Simulate Release

- Location by mouse click
- Select chemical (1300+)
- Enter quantity (mass or volume)
- Enter spill duration
- Specify simulation duration



## •Run Water/Air Quality Models

- CE-QUAL W2
- CAMEO
- Started from GIS interface
- Model fed from chemical database and weather data



## •Import and Display Model Results

- Multiple CE-QUALW2 model outputs
  - GIS layers depict stages of spill
  - Animate spill progression
  - Display output at surface, bottom, 1, 2, and 3 meter depths
- Detailed GIS layers for reference, routing, mitigation, and protection



## •Perform Mitigation

- Locate nearest responders and facilities (using GIS layer contact information)
- Predict where spill will be in future
- Estimate population and ecological exposure
- Perform “what-if” scenarios (e.g., increase/decrease water release from upstream/downstream flow control structures)

# **Scenario Demonstration**

# Scenario

- **Location:** Cheatham Reach - RM 194
- **Incident:** Barge Grounding
- **Release:** 25,000 barrels ( $1.05 \times 10^6$  gallons) over 30 minutes
- **Chemical:** ethylene glycol
- **Meteorology:** 10 mph easterly wind, 70° F, partly cloudy

# SMIS Input

**QUALW2- INPUT PARAMETERS**

**CONSTITUENT**

Name: Ethylene glycol

☒ Volume 1050000 Gallons

☐ Mass Enter Spill Mass Kg

**LOCATION OF SPILL INCIDENT**

Waterway Name: Cumberland River

Segment ID: 87 Zoom to Segment

**SIMULATION**

Start Date(MM:DD)/Time(HR:MIN)

12 1 / 12 0

Same as Spill Start Date/Time

Select constituent

Duration: ☒ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 days

**SPILL DURATION**

Start Date(MM:DD)/Time(HR:MIN)

12 1 / 12 0

End Date(MM:DD)/Time(HR:MIN)

12 1 / 12 30

Run Map Output Close Help

# SMIS Flow Settings (Live)

**Dam Flow Settings** [X]

Change Live Dam Flow and Weather File

**OLD HICKORY DAM FLOW**

☒ Live Connection      FLOWRATE: 12200      Cu, Feet/sec ▼

☐ Enter Flow

DURATION:      Start(MM:DD:HR)      End(MM:DD:HR)

Same as Simulation Duration      12   1   12   [Calendar]      12   2   12   [Calendar]

**PERCY PRIEST DAM FLOW**

☒ Live Connection      FLOWRATE: 500      Cu, Feet/sec ▼

☐ Enter Flow

DURATION:      Start(MM:DD:HR)      End(MM:DD:HR)

Same as Simulation Duration      12   1   12   [Calendar]      12   2   12   [Calendar]

**CHEATHAM DAM FLOW**

☒ Live Connection      FLOWRATE: 13800      Cu, Feet/sec ▼

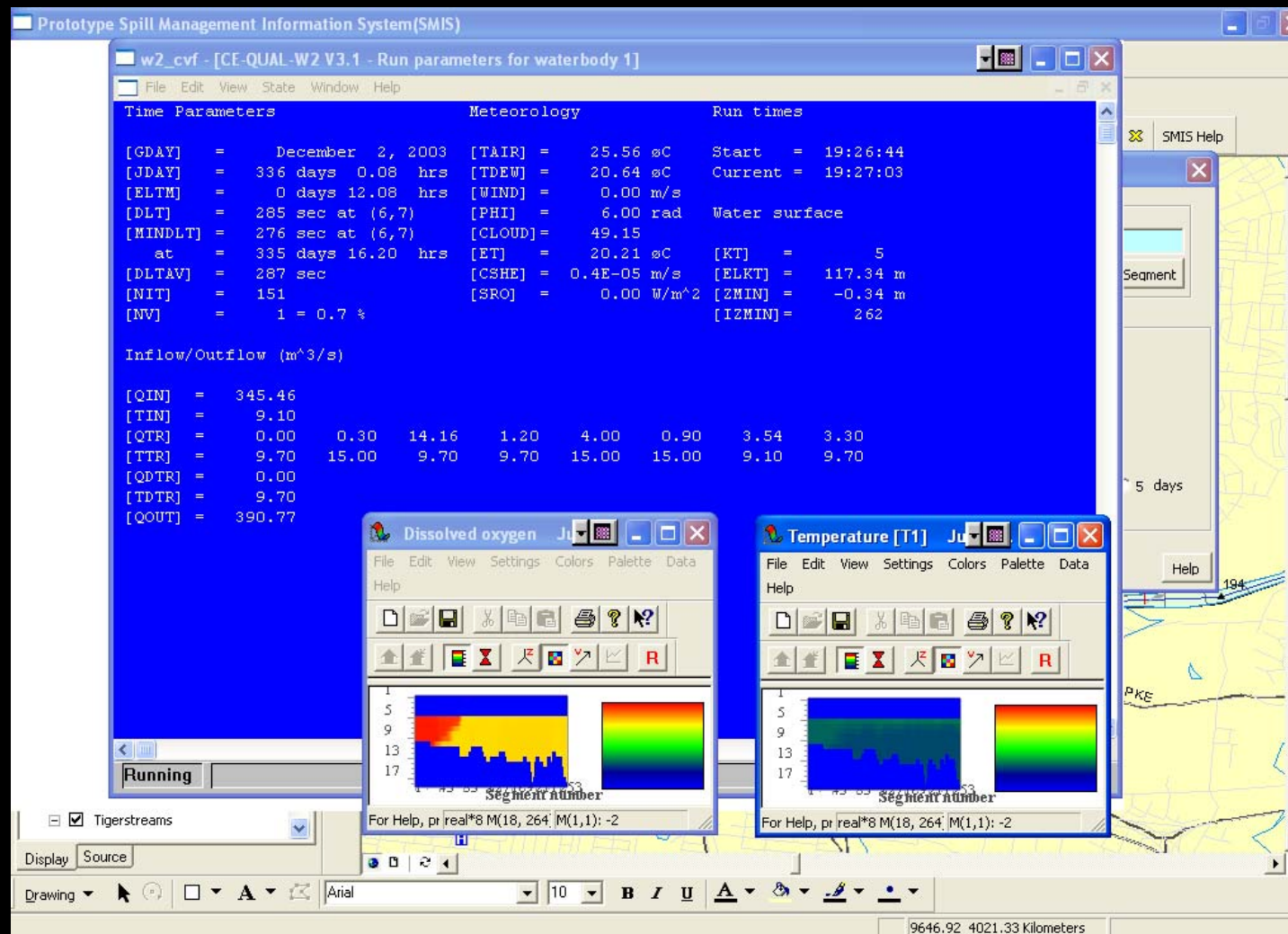
☐ Enter Flow

DURATION:      Start(MM:DD:HR)      End(MM:DD:HR)

Same as Simulation Duration      12   1   12   [Calendar]      12   2   12   [Calendar]

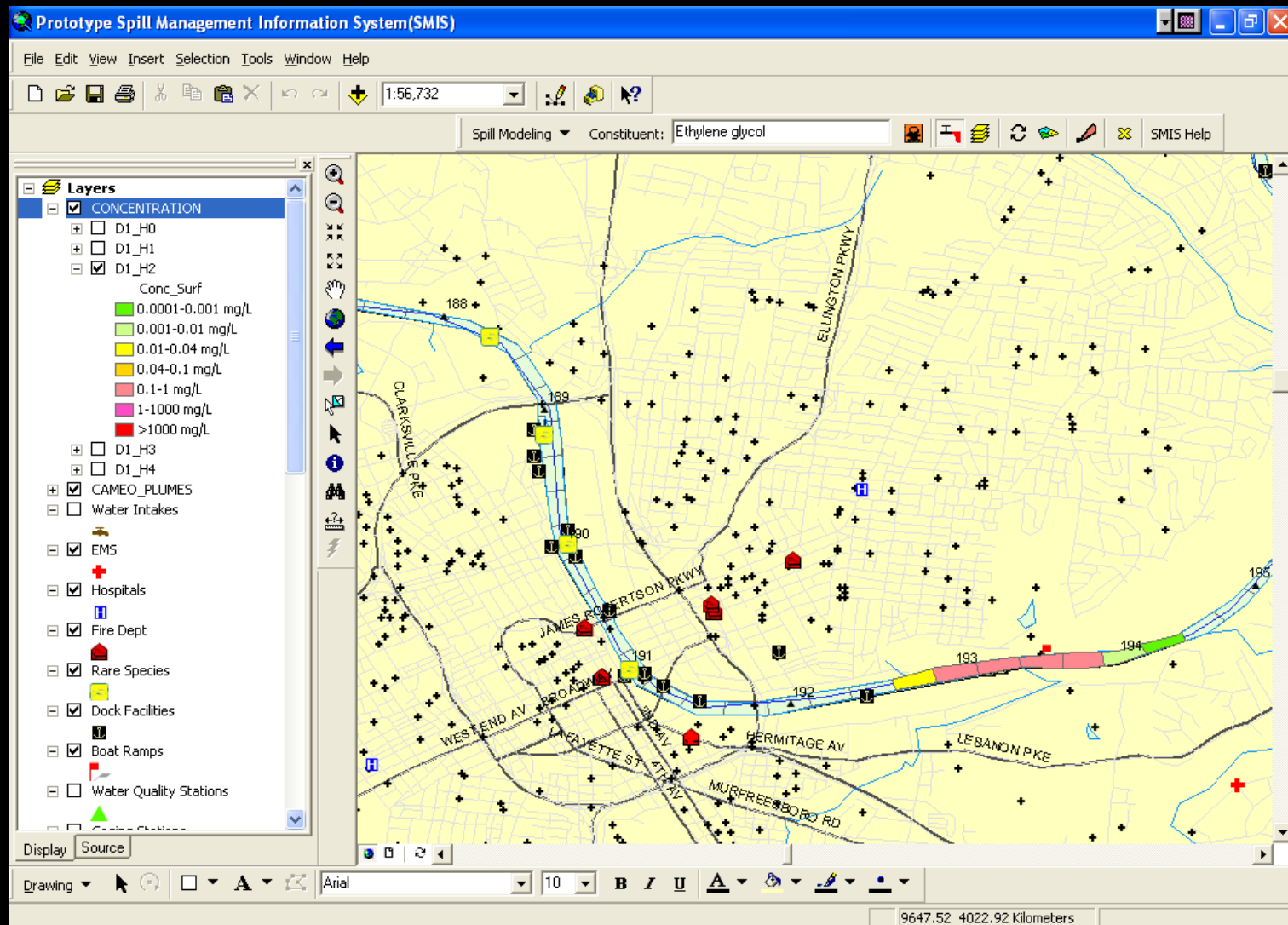
Ok

# CE-QUAL-W2 Model Execution

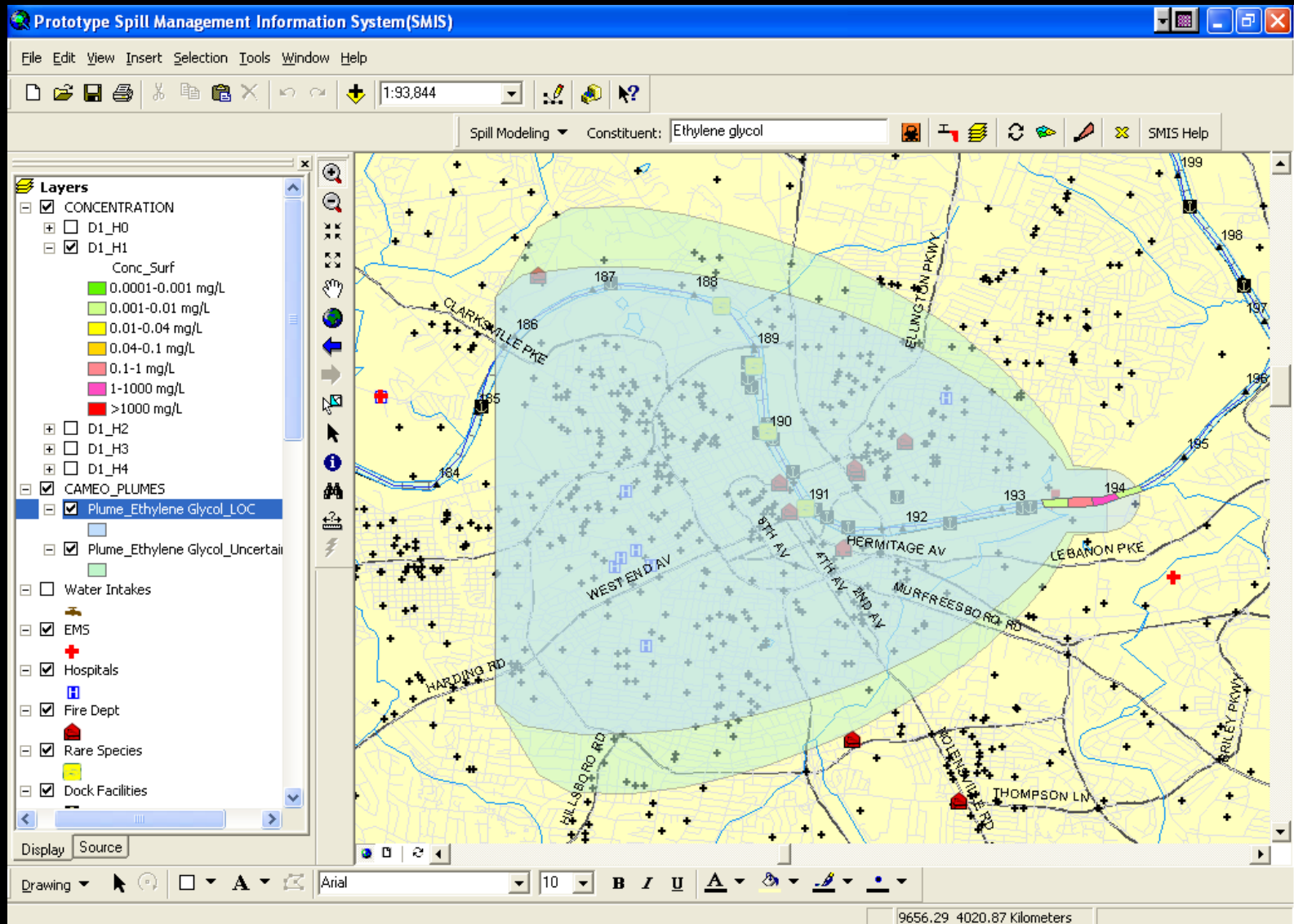




# Spill Progression – 2 hours



# Air Dispersion – 1 hour



# Analysis and Abatement Routines

- **Animation Tool** – toggles on/off layers in succession to create dynamic viewing of spill incident progression
- **GIS Risk Analysis Routines** – search for sensitive receptors within generated GIS layers (water intakes, endangered species, population centers) and associated attributes (contact numbers, responders, HAZMAT teams)
- **Locating Access Points** – boat launches, bridges, dock facilities, etc.

# **Key Project Accomplishments**

- **Completed information system design for managing spills on waterways**
- **Deployed state-of-the-art information model, data, and technologies**
- **Established proof of concept that a comprehensive Spill Management Information System is feasible**

# Current/Future Directions

- **Utilize existing system for spill management training, planning exercises, and operations**
  - SMIS exercise with federal/state/local agencies conducted in October 2003
- **Modular design allows for:**
  - Application to different waterways
  - Use of different prediction models
  - Validation of existing models
- **Development of additional interpretation tools:**
  - Automate identification of proximate responders and endangered receptors
  - Locate vulnerable areas along the waterway
  - Rapid queries that identify key facilities & access points
- **Provide remote Internet capability (with security)**

# Potential Applications and Developmental Options

## **Model enhancements to existing Cheatham Reach may include:**

- **Threat zone analysis queries to evaluate where a spill might occur that could threaten particular areas (e.g., endangered species areas, water intakes, schools, businesses, homes, etc.);**
- **Notification systems that can provide contact lists for facilities in affected areas, to include automated calling;**
- **Web-based SMIS to provide portability to first responders in the field (including employment of proper security measures to ensure access to SMIS is limited to authorized users);**
- **Resource analysis to help estimate the level of response needed to adequately address impacts of modeled spills, and the quantity of a particular resource that could be impacted by given spills (e.g., equipment required to isolate a specific endangered species area or water intake zone, such as length of boom, number of transport trucks, number of boats, number of personnel);**
- **Improved reactivity and transport capability within CE-QUAL-W2 to allow for inclusion of the effects of contaminant volatilization, reaction, and/or sorption; and**
- **Improved air dispersion model capabilities (nuclear, biological capability (HPAC))**

# Potential Applications and Developmental Options

## **Transferability of Cheatham Reach SMIS to Similar Waterway Systems:**

- SMIS can be readily adapted to other waterways that can be effectively modeled with CE-QUAL-W2.
- Suggested prioritization of work includes other major population centers and/or large volume transportation sectors possessing similar water hydrodynamics to the Cheatham Reach of the Cumberland River.
- Required enhancements:
  - Incorporation of GIS layers representative of the geographic area of interest;
  - Development and calibration of CE-QUAL-W2 model to waterway of interest, to include:
    - Waterway bathymetry
    - Collection of appropriate flow and water quality data;
  - Establishment of 'hot links' to meteorological and water flow data; and
  - Installation and training.

# Potential Applications and Developmental Options

## **Model enhancements for dissimilar waterway systems:**

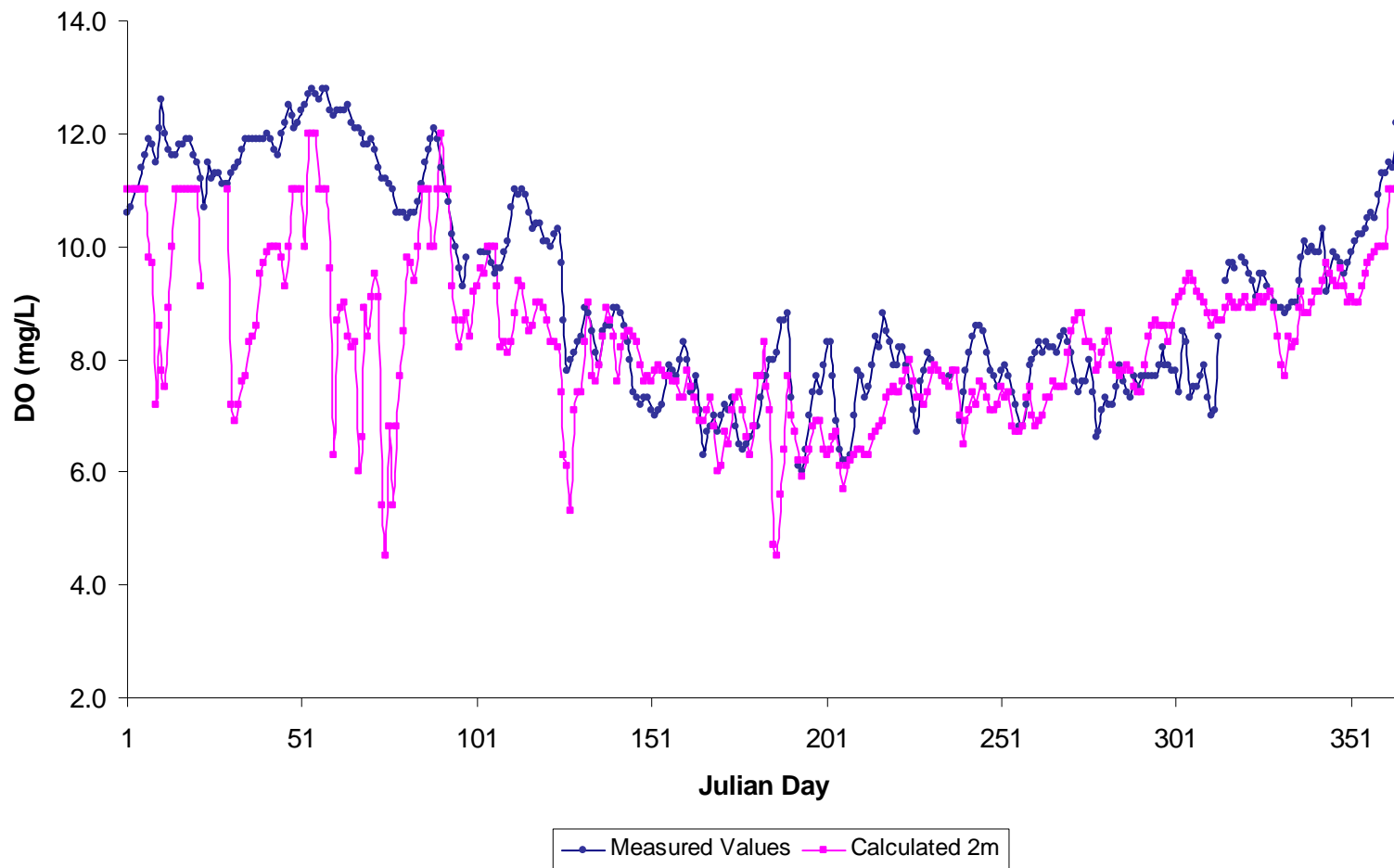
- **Modular framework of SMIS allows employment of additional water quality models to more appropriately model water bodies possessing hydrodynamics that are dissimilar to those modeled by CE-QUAL-W2.**
- **Such systems may include Resource Management Associates 2 (RMA-2) and Resource Management Associates 4 (RMA-4), and others.**
- **Required enhancements:**
  - **Evaluation of the waterway and needs of the client to determine the most appropriate hydrodynamic and contaminant transport models;**
  - **Incorporation of GIS layers representative of the geographic area of interest;**
  - **Development and calibration of the hydrodynamic and contaminant transport models of interest, to include:**
    - **Waterway bathymetry**
    - **Collection of appropriate flow and water quality data;**
  - **Design and implementation of applications module to activate and integrate model functionality within SMIS;**
  - **Establishment of 'hot links' to meteorological and water flow data; and**
  - **Installation and training.**



**Questions?**

# CE-QUAL-W2 Calibration

1999 Calibration Data - DO - Default Coefficients



# CE-QUAL-W2 Calibration

